"Renewable Energy Optimization for Net-Zero"

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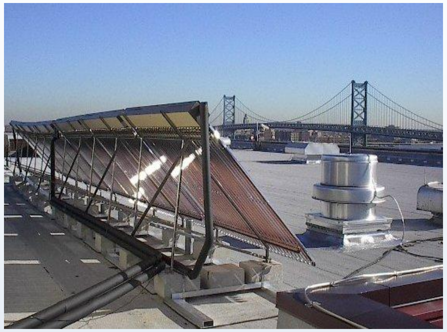
Combining Renewable Energy Measures

Photovoltaics

Wind Power

Solar Water Heating



Solar Vent Air Preheat

Concentrating Solar Heat/Power

Biomass Heat/Power

Daylighting

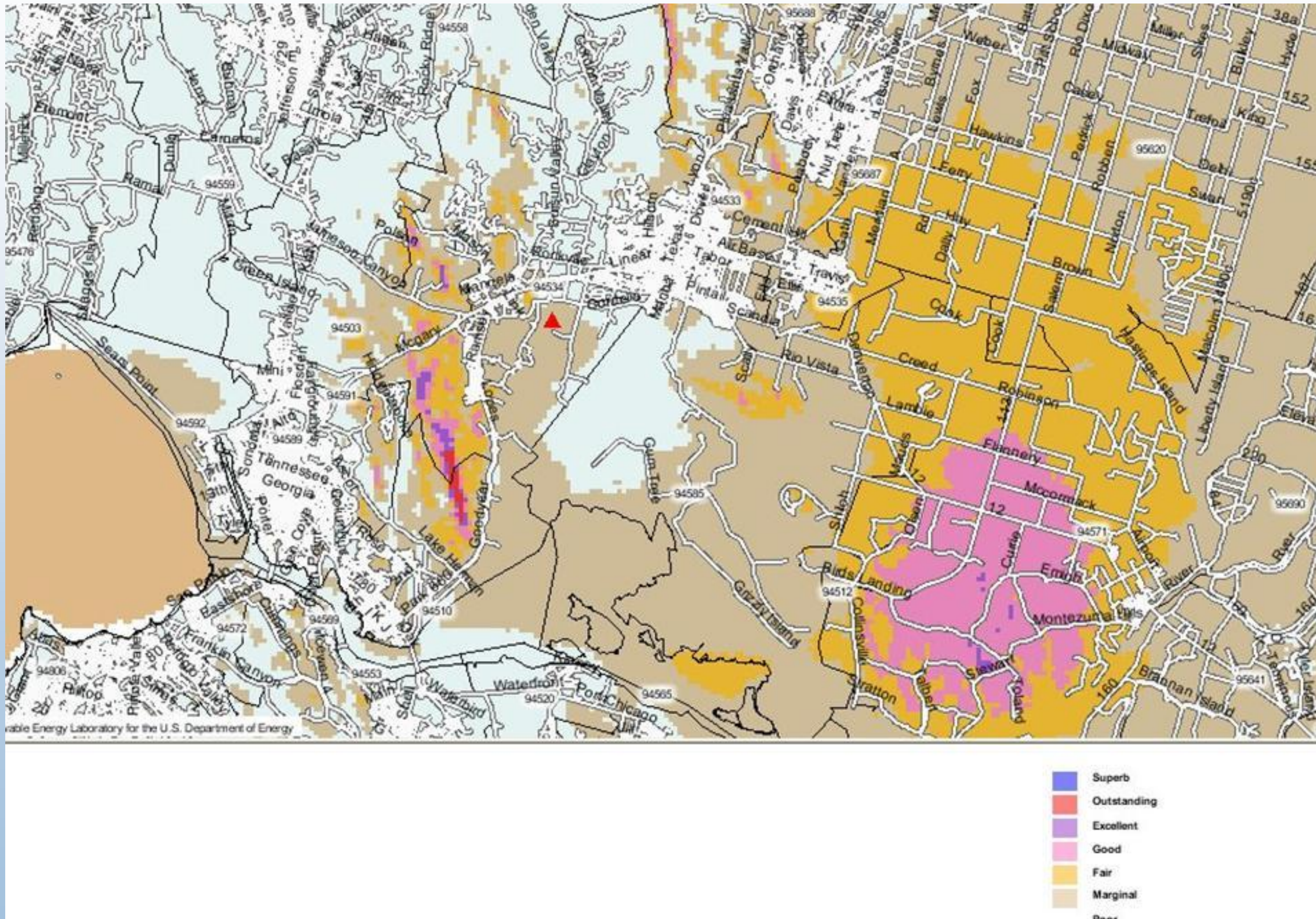
Ground Source Heat Pump

Landfill Gas

Best Mix of Renewable Energy Technologies Depends on:

- Renewable Energy Resources
- Technology Characterization
  - Cost ($/kW installed, O&M Cost)
  - Performance (efficiency)
- Prevailing Utility Rates
- State, Utility and Federal Incentives
- Economic Parameters
  - Discount rates
  - Fuel Escalation Rates
- Statutes, Regulations, Mandates

Example of NREL GIS Data
Wind Energy in vicinity of Fairfield CA



NREL National Renewable Energy Laboratory

"Everything should be made as simple as possible, …

…but not simpler."

Albert Einstein

Technology Characteristics
Heuristic Models

Cost

(Size, m2)*(Unit Cost, \$/m2)

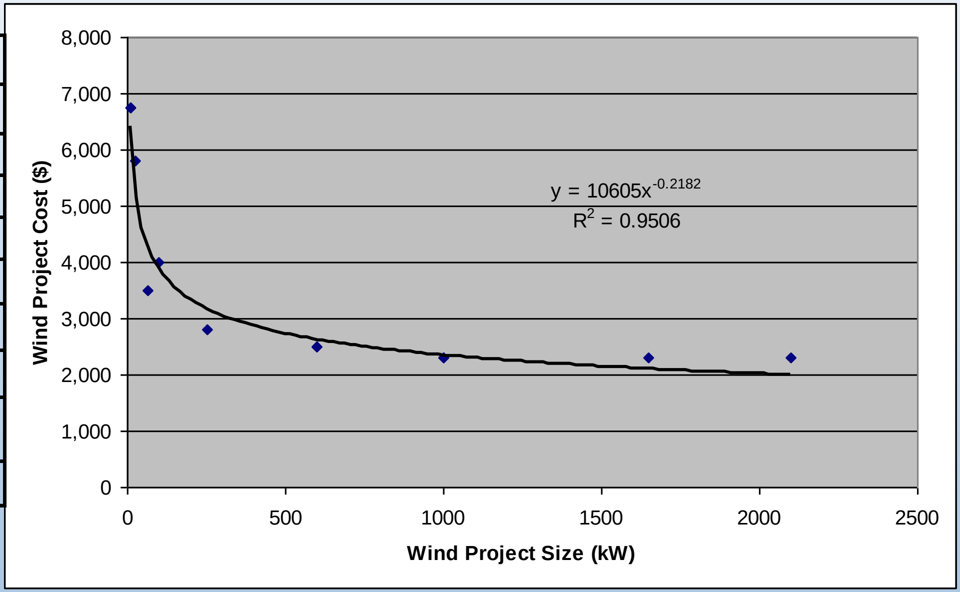
Heuristic values

Performance

(Size, m2)*(Resource, kWh/m2)*(efficiency)

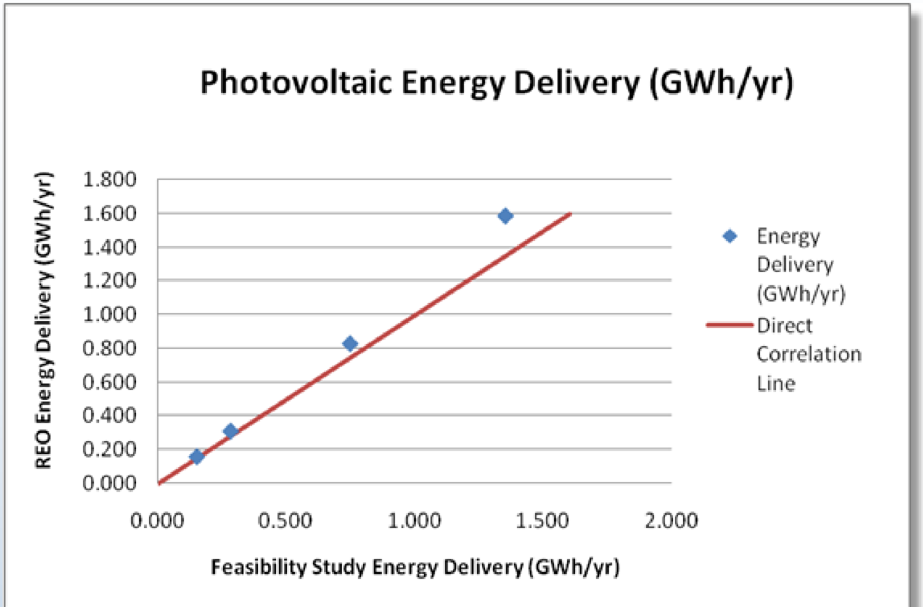
Technology Characteristics: Wind Power

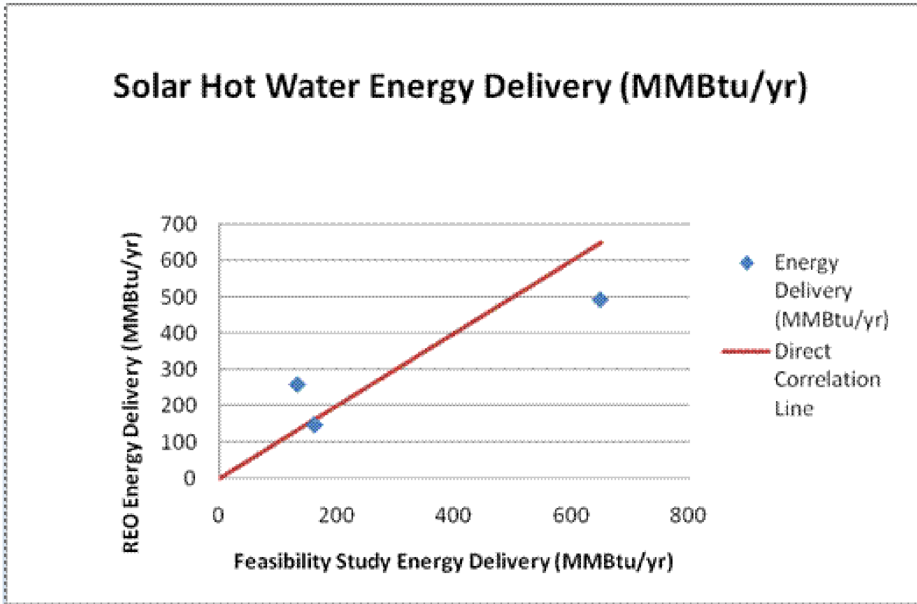
Tower Height	2.5	times blade length, m
Wind Shear Exponent	0.115	
acres per MW	60	
Wind Turbine Efficiency	28%	
Wind Speed Turbine Rate	15	m/s
Capital Cost	$10,605	$/kW
	-0.2182	
O&M Cost	7.9	$/year/kW
Minimum Capital Cost	2000	$/kW
Maximum Capital Cost	11000	$/kW

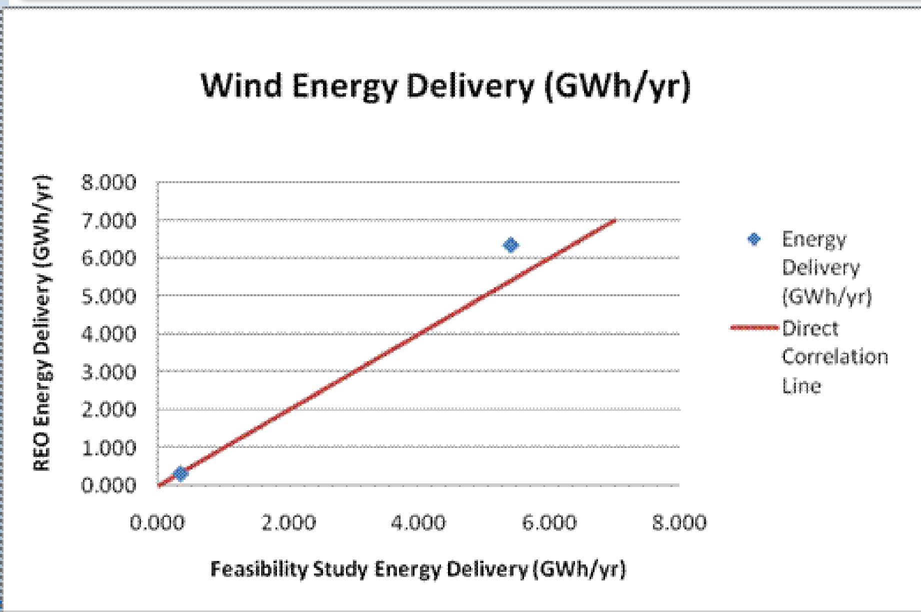


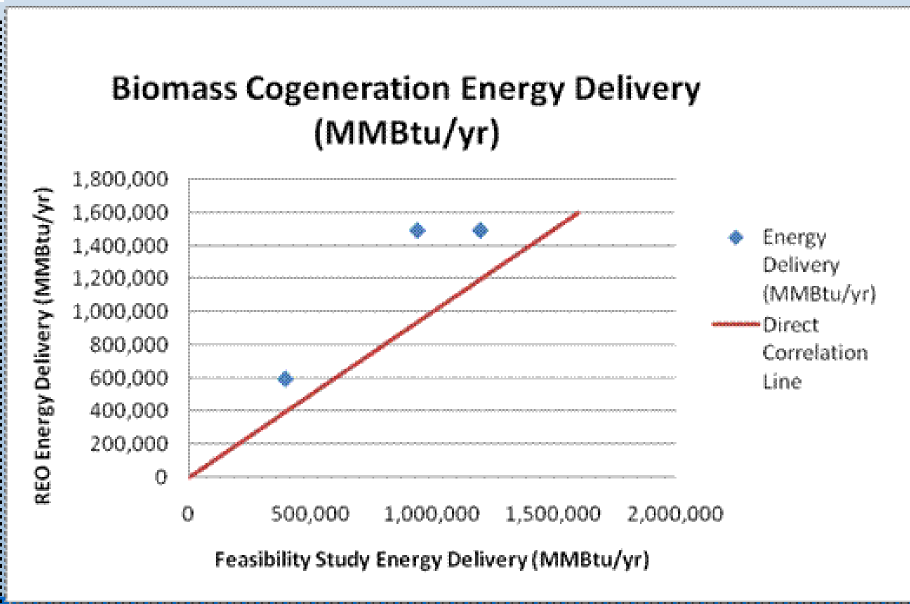
PG&E Available Funding and Program Statistics (updated 06/05/07)
http://www.pge.com/suppliers_purchasing/new_generator/incentive/available_funding_and_program_statistics.html

Comparison of TEAM REO and Site Visit Reports for DOE Sites

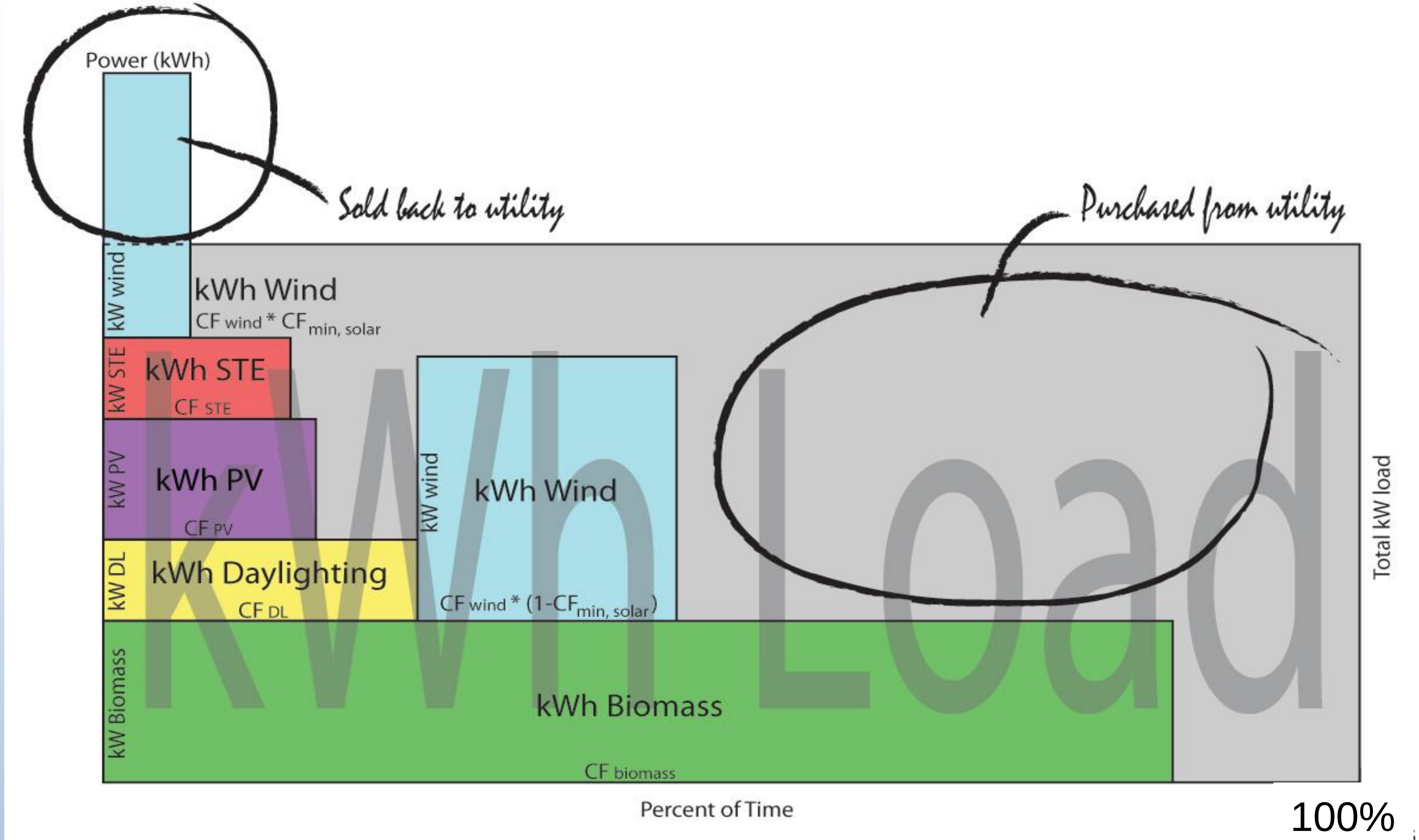






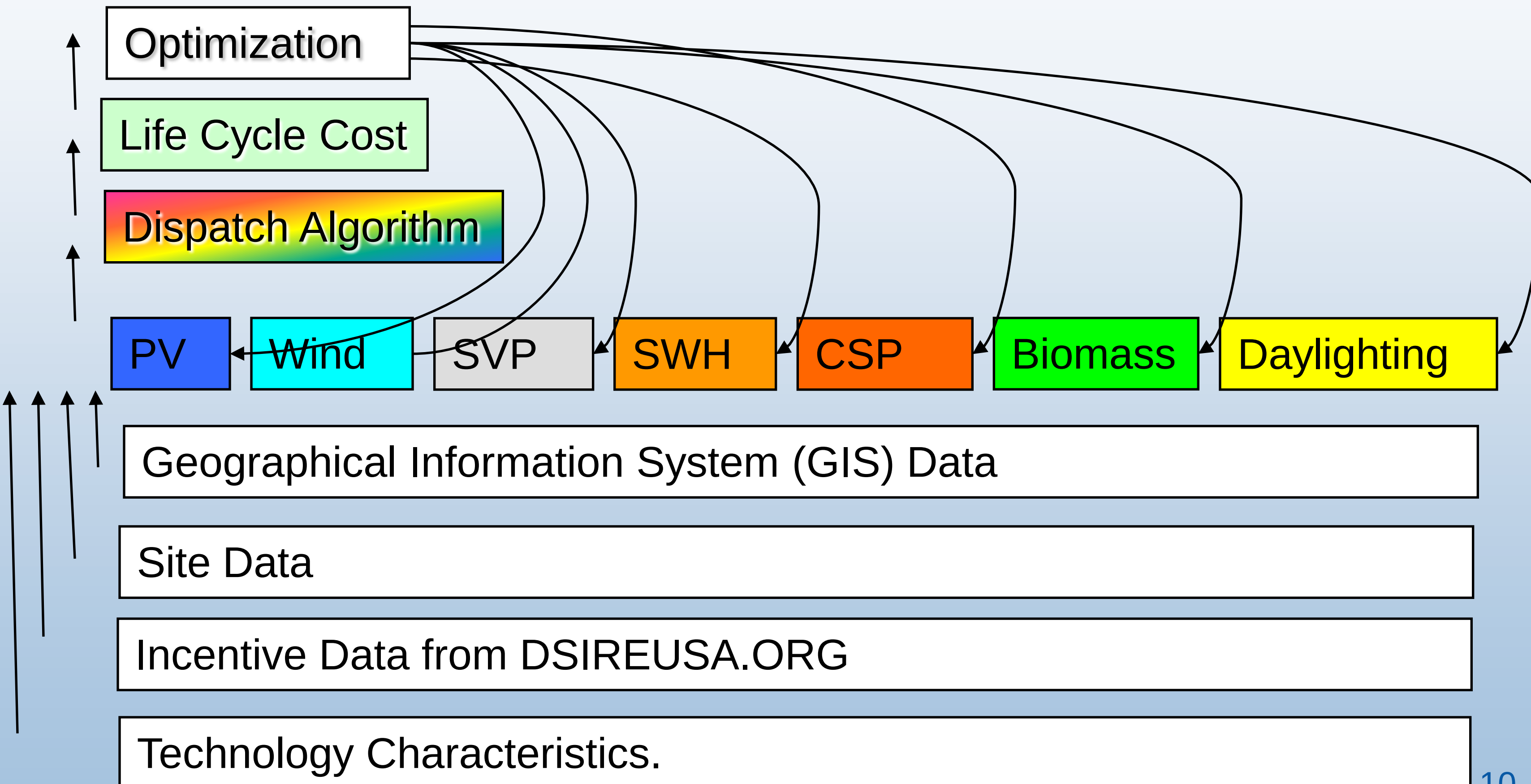


Stochastic Integration of Renewable Energy Technologies by the method of Polynomial Expansion (SIRET)



This simplified figure shows seven possible states the system could be in, but the model actually has 128 states for seven technologies.

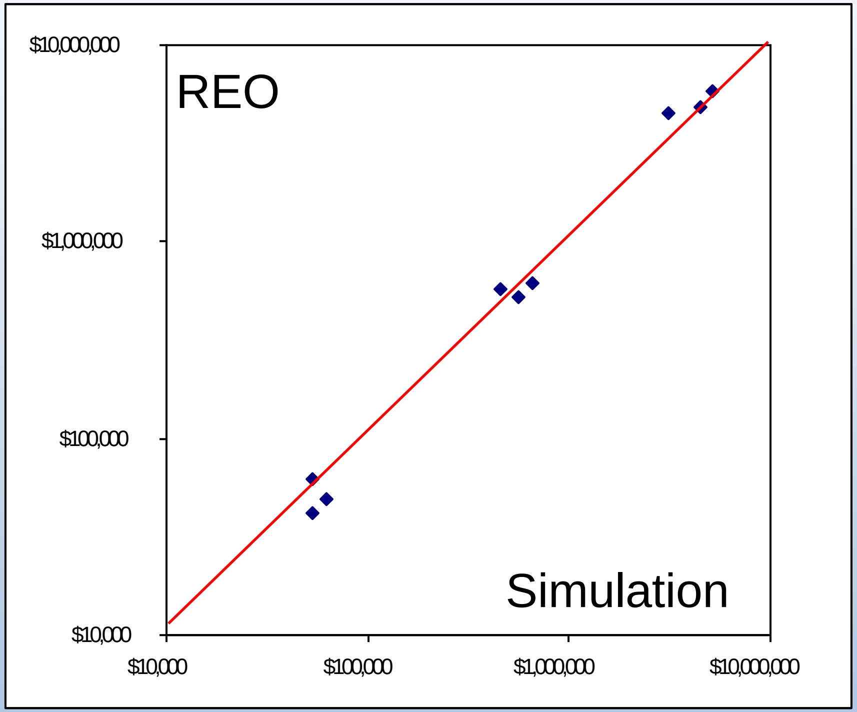
Optimization Procedure



Compare/Contrast with Hourly Simulation

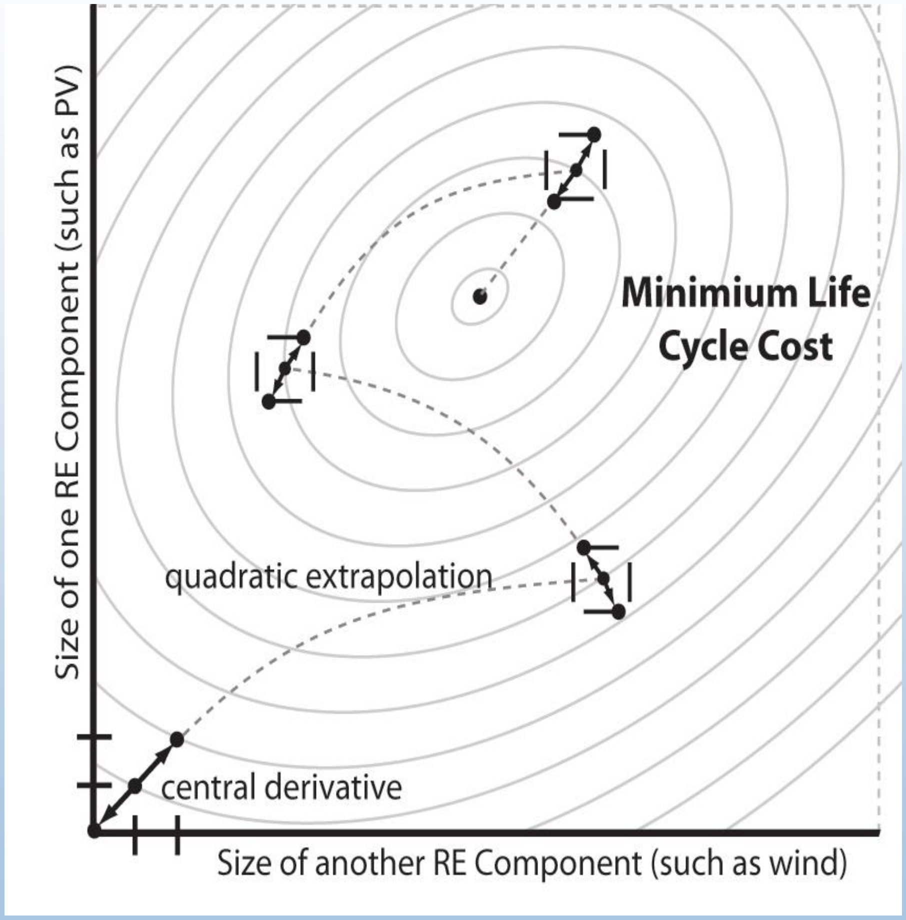
Life Cycle Cost ($)

	Hourly Simulation	REO
CO Commercial	$655,076	$614,862
CO Industrial	$5,158,624	$5,870,856
CO Residential	$62,117	$49,463
WA Commercial	$460,039	$568,455
WA Industrial	$3,149,595	$4,533,277
WA Residential	$53,587	$62,304
AZ Commercial	$555,003	$522,448
AZ Industrial	$4,469,720	$4,891,129
AZ Residential	$53,567	$41,256



Comparison of Annual Average and Hourly Simulation in Renewable Energy Technology System Sizing
Christine L. Lee, *University of Colorado at Boulder, 2009*

Optimization Problem



Determine the least cost combination of renewable energy technologies for a facility

Objective: Minimize Life Cycle Cost ($)

Variables: Size of Each Technology (kW of PV, kW of wind, etc)

Constraints: such as 100% of energy from renewables

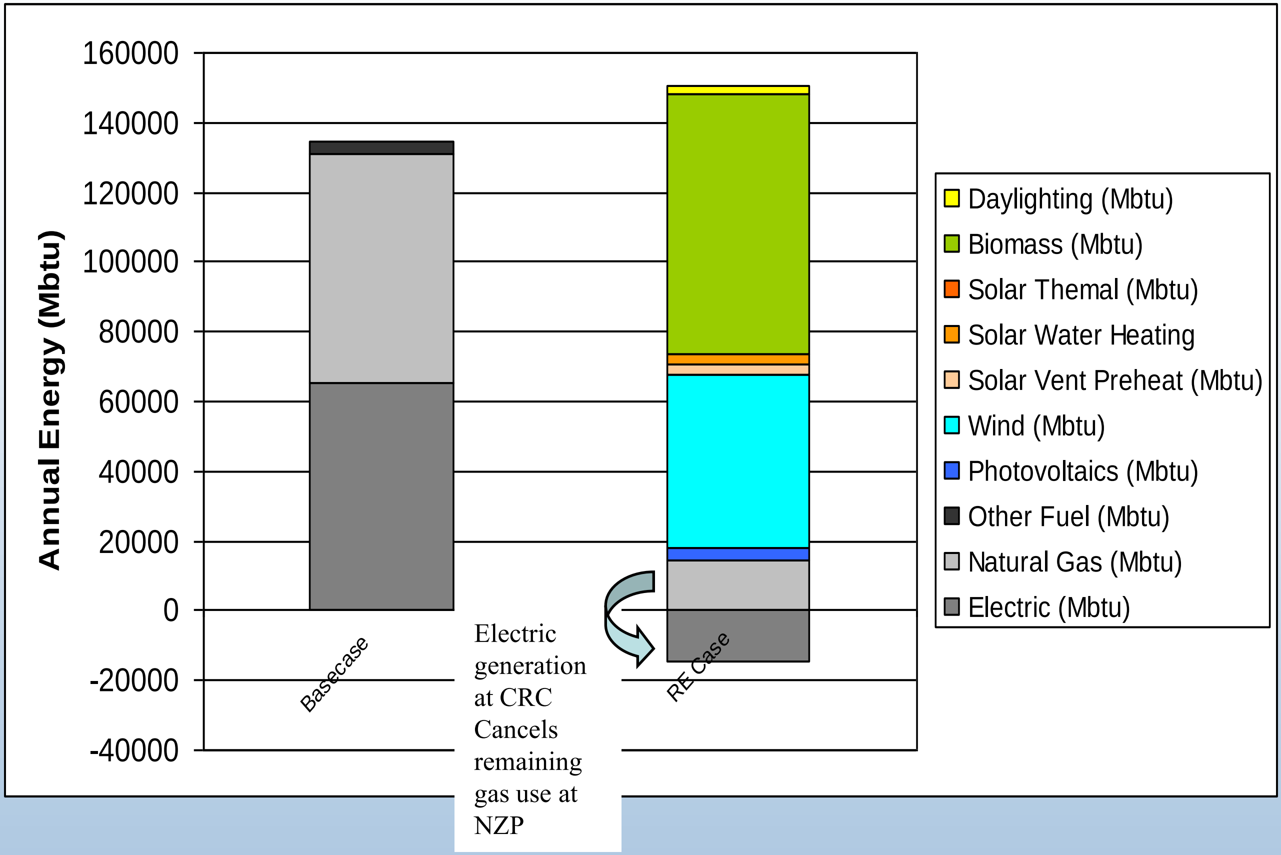
Variables in the Optimization

1. kW of photovoltaics
2. kW of wind power
3. Sf of solar water heating
4. Sf of solar ventilation air preheating
5. Sf of solar parabolic trough collectors
6. Thermal storage (therms)
7. kW of solar thermal electric cogeneration
8. Mbtu of biomass gasifier capacity
9. kW of biomass gasifier cogeneration
10. Ft3 of biomass anaerobic digester
11. kW of biomass anaerobic digester cogeneration
12. Percent ceiling area skylights for daylighting
13. MCF of landfill gas collection system
14. kW of landfill gas cogeneration
15. Tons of ground source heat pump capacity

Examples of Renewable Energy Optimization (REO) Net-Zero Analysis

- National Zoo, DC
- Frito Lay North America plants (7)
- San Nicolas Island, CA
- USCG REPFAC Hawaii
- Shoshone Net Zero National Forest
- Others….

REO Example: Net Zero Zoo National Zoological Park (NZP) and Conservation Research Center (CRC), Washington DC

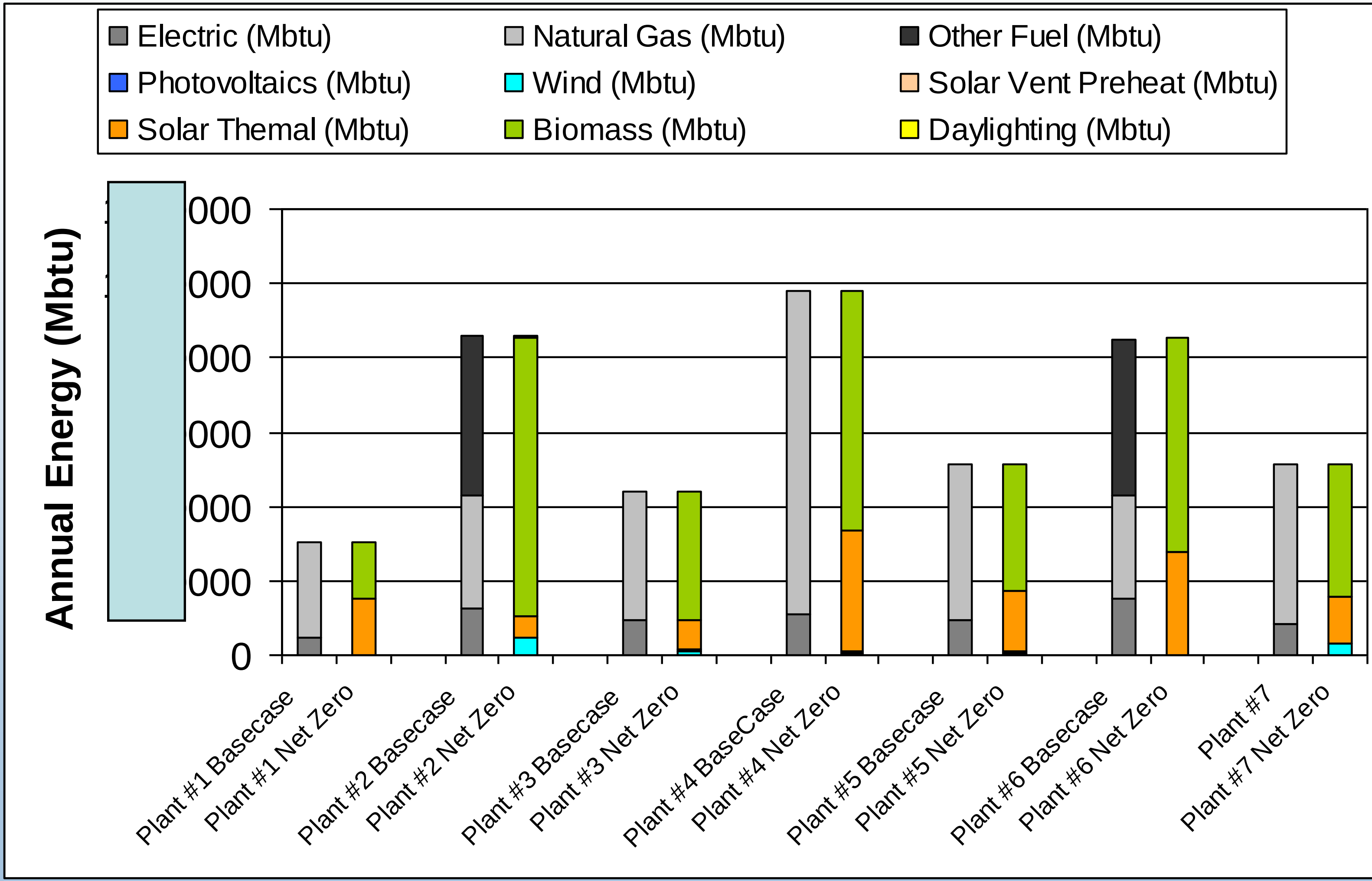


	Photovoltaics Size (kW)	Wind Capacity (kW)	Solar Vent Preheat Area (ft2)	Solar Water Heating Area (ft2)	Biomass Gasifier Size (M Btu/h)	Biomass Cogeneration Size (kW)	Anaerobic Digester Size (FT3)	Anaerobic Digester Cogeneration Size (kW)	Daylight Aperture (Skylight) Area (ft2)
Natl. Zoological Park, DC	638	0	10655	7,535	10.996	1,168	3,723	12	21221
Cons. Res. Cntr., VA	224	14,500	8,075	2,180	0.000	0	459	0	6476
Total	862	14,500	18,730	9,715	10.996	1,168	4,182	12	27697

REO Example (continued): Net Zero Zoo
National Zoological Park (NZP) and Conservation Research Center (CRC), Washington DC

Name	Basecase Life Cycle Cost ($)	RE Case Life Cycle Cost ($)
Initial Cost	$0	$45,858,421
O&M Cost	$0	$13,135,266
Biomass Fuel Cost	$0	$5,762,545
Gas Cost	$17,323,188	$5,713,053
Electric Cost	$34,914,085	$7,196,488
Production Incentives	$0	-$2,887,806
Total	**$52,237,272**	**$74,777,968**

Example: Frito Lay North America
Minimum Life Cycle Cost (Net Zero constraint)



Example: Frito Lay Optimization for Seven Manufacturing Plants Constraint: Net Zero

	Photovoltaics Size (kW)	Wind Capacity (kW)	Solar Vent Preheat Area (ft2)	Solar Thermal Area (ft2)	Biomass Boiler Size (M Btu/h)	Biomass Cogeneration Size (kW)	Daylighting Office Utility Skylight/Floor Area Ratio	Daylighting Warehouse Skylight/Floor Area Ratio
Plant #1	200	491	5456	509196	19	1669	2.2%	2.1%
Plant #2	0	6187	8953	391987	87	3097	3.8%	2.0%
Plant #3	0	3107	13098	469621	44	3180	4.9%	3.6%
Plant #4	1011	1000	10213	1360535	78	4108	3.4%	1.8%
Plant #5	1003	998	10327	704140	44	3327	6.1%	3.4%
Plant #6	0	0	10322	1529609	74	6020	err	err
Plant #7	0	3699	10802	673761	43	2193	3.3%	3.7%

"All the News That's Fit to Print"

The New York Times

VOL. CLVII . . . . No. 54,129 + THURSDAY, NOVEMBER 15, 2007

In Eco-Friendly Factory, Low-Guilt Potato Chips

Frito-Lay's Venture Joins the Rush to Be Green

By ANDREW MARTIN

CASA GRANDE, Ariz. — At Frito-Lay's factory here, more than 500,000 pounds of potatoes arrive every day from New Mexico to be washed, sliced, fried, seasoned and portioned into bags of Lay's and Ruffles chips. The process devours enormous amounts of energy, and creates vast amounts of wastewater, starch and potato peelings.

Now, Frito-Lay is embarking on an ambitious plan to change the way this factory operates, and in the process, create a new type of snack: the environmentally benign chip.

Its goal is to take the Casa Grande plant off the power grid, or nearly so, and run it almost entirely on renewable fuels and recycled water. Net zero, as the concept is called, has the backing of the highest levels of corporate executives at PepsiCo, the parent of Frito-Lay.

There are benefits besides the potential energy savings. Like many other large corporations, PepsiCo is striving to establish its green credentials as consumers become more focused on climate change. There are marketing opportunities, too. The company, for example, intends to advertise that its popular SunChips snacks are made using solar energy.

"We don't know what the complete payoff for net zero is going to be," said Indra K. Nooyi, PepsiCo's chairman and chief executive. "If this works even to 50 or 60 percent of its potential, that is fantastic, and it's so much better than what we already have."

From coast to coast, more companies are thinking about how much fossil fuel they use and ways to conserve energy. Venture capital money is also pouring into fledgling green technology.

Only a few years ago, Andy Walker, a government engineer, pleaded with companies to tackle the problems but got blank stares. "Now, my phone is ringing off the hook," said Mr. Walker, who works at the National Renewable Energy Laboratory of the Department of Energy in Colorado.

But advocacy groups contend that for all the interest in saving energy, many companies also exaggerate small improvements for marketing purposes.

"Now I think there's a transi-

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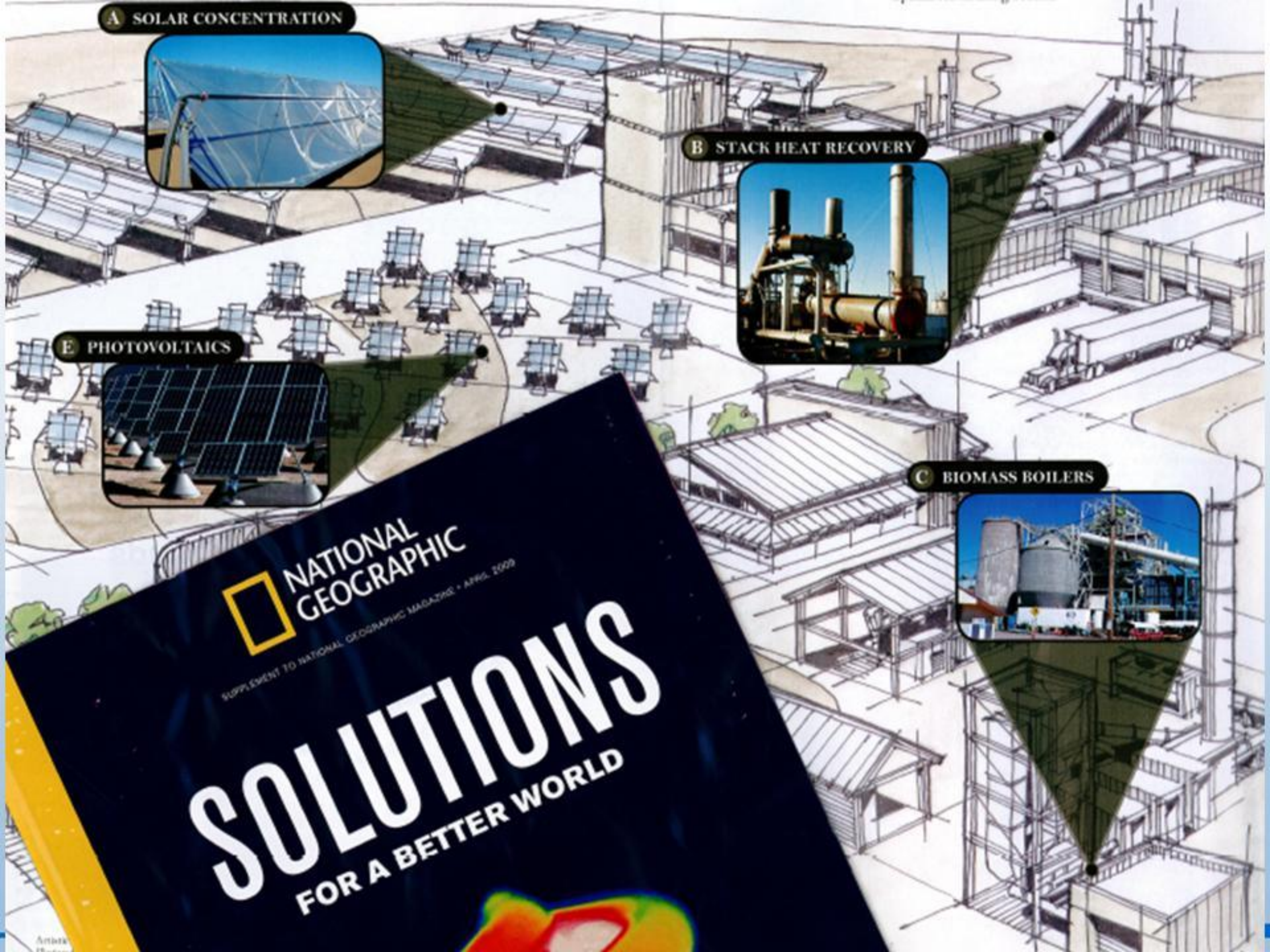
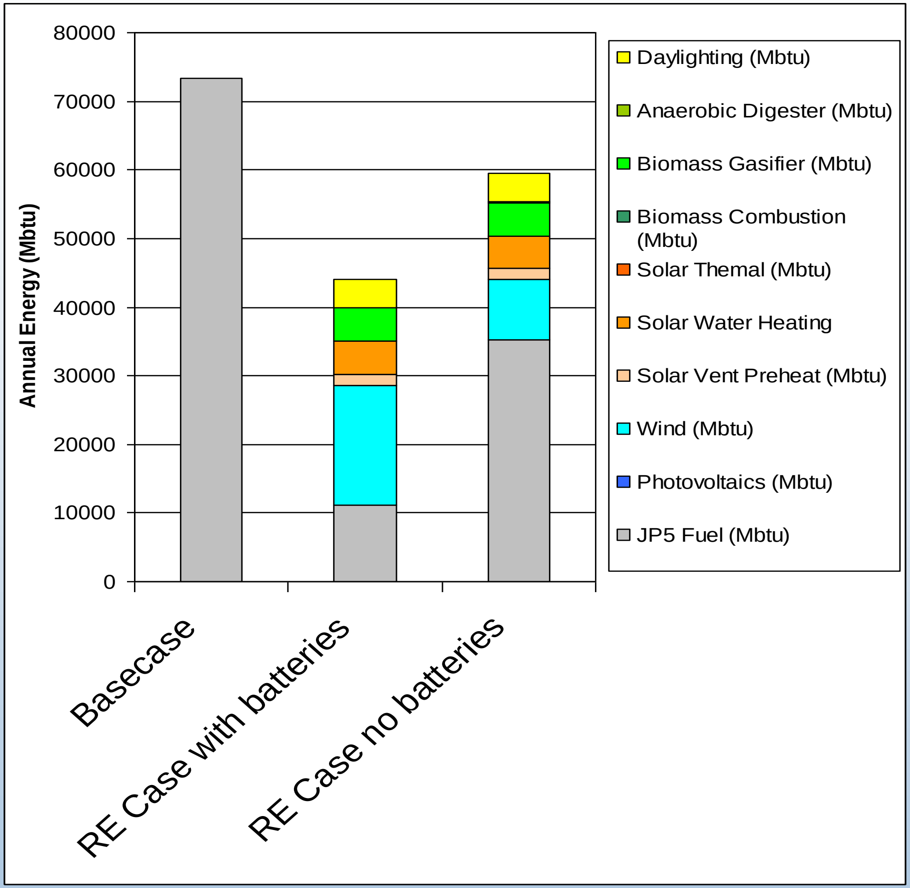

A SOLAR CONCENTRATION
B STACK HEAT RECOVERY
C BIOMASS BOILERS
E PHOTOVOLTAICS
NATIONAL GEOGRAPHIC
SUPPLEMENT TO NATIONAL GEOGRAPHIC MAGAZINE • APRIL 2009
SOLUTIONS
FOR A BETTER WORLD

REO Example: Minimize Life Cycle Cost
US Navy San Nicolas Island CA



	Wind Capacity (kW)	Solar Vent Preheat Area (ft2)	Solar Water Heating Area (ft2)	Anaerobic Digester Size (FT3)	Anaerobic Digester Cogeneration Size (kW)	Daylight Aperture (Skylight) Area (ft2)
Building Measures	0	10437	15,441	209	0	12712
Central Plant	644	0	0	0	0	0
Total	644	10,437	15,441	209	0	12712

USCG Facility

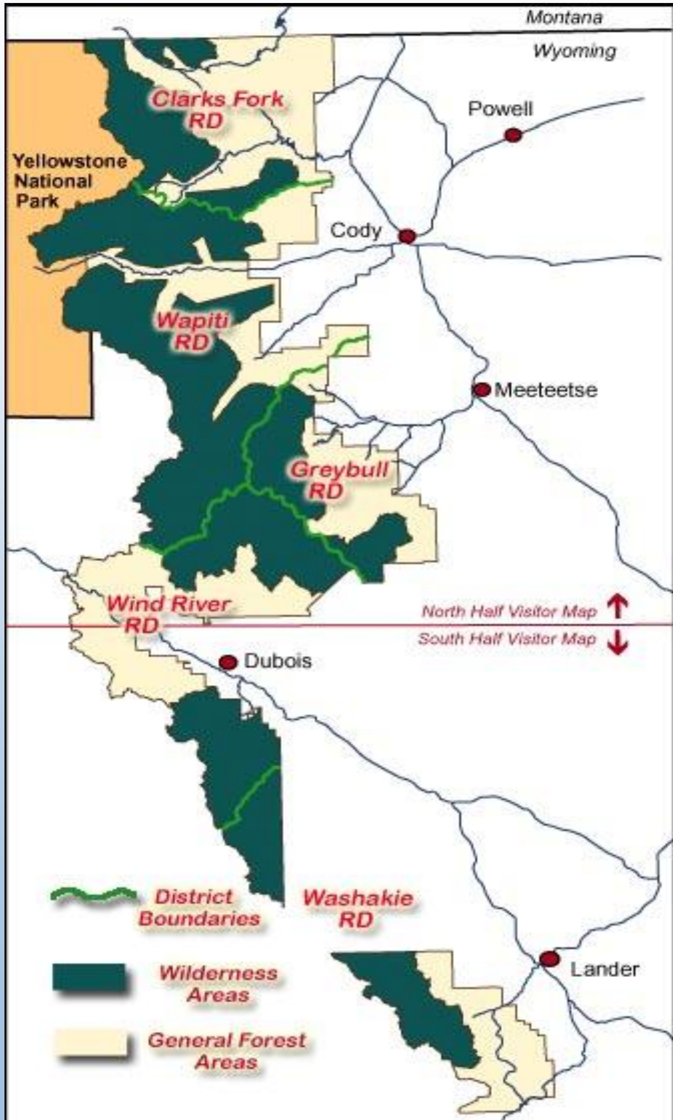
Diamond Head, HI
with incentives

Initial Cost for Renewable Energy Projects ($)	$90,868
Annual Electric Savings (kWh/year)	39,074
Annual Cost Savings ($/year)	$5,972
Simple Payback Period (years)	15.2
Rate of Return	7.0%
Percent Renewables	100%

Sizes of Each Technology:

Photovoltaics (kW)	14.6
Wind Energy (kW)	2.4
Solar Water Heating (sf)	137.8
Skylight Area (sf)	272.4

Shoshone Net Zero National Forest



Initial Cost for Renewable Energy Projects ($)	$2,066,502
Annual Electric Savings (kWh/year)	1,279,090
Annual Gas/Fuel Savings (therms/year)	6,467
Annual Cost Savings ($/year)	$11,484
Simple Payback Period (years)	180.0
Rate of Return	-7.0%
Percent Renewables	100.0%
Life Cycle Savings ($)	-$1,680,866

Photovoltaics (kW)	47
Wind Energy (kW)	563
Solar Ventilation Air Preheat (sf)	4183
Solar Water Heating (sf)	305

“Simplicity is quite often the mark of excellence.”
-Allen Bennett, SMDC

“It's so much easier to suggest solutions when you don't know too much about the problem.”

- *Malcolm Forbes*

Thank You!

Andy Walker
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